Physico-chemical Properties of Soil Samples and Dumpsite Environmental Impact on Groundwater Quality in South Western Nigeria

B. S. Badmus[1], V. C. Ozebo[1], O. A. Idowu[2], S. A. Ganiyu[1,*] and O. T. Olurin[1]
[1]*Department of Physics, Federal University of Agriculture Abeokuta, Ogun State, Nigeria*
[2]*Department of Water Resources and Agrometeorology, Federal University of Agriculture Abeokuta, Ogun State, Nigeria*

Physiochemical and microbial analysis of water samples from hand-dug wells were carried out around active dumpsite and/or of soil samples to ascertain the effect of wastes on the groundwater and soil quality. Soil samples were collected up to a depth of 100cm with the aid of soil auger while water samples were collected inside a 2L PVC bottle. Soil pH, EC, % OM, %OC values ranged from 5.45-6.45, 5.03-6.63, 2.39-9.14, and 1.39-5.30. The mean values of soil's pH, EC, % OM, %OC are high when compared to control. For water samples, the parameters of interest for microbial analysis are: coliform count and E. coli while parameters determined for physiochemical analysis are: pH, Total Dissolved Solid (TDS), Electrical Conductivity (EC), Hardness, Carbonate, Bicarbonate, Chloride, Nitrate, Sulphate, Calcium, Magnesium, Potassium and Sodium ions. Microbial analysis revealed severe pollution in all samples while most of physiochemical parameters indicated traceable pollution, which were below the World Health Organization (WHO) standard for human consumption as well as the Nigerian Standard for Drinking Water Quality (NSDWQ) limits. However, Well 5 which is close to the landfill has high values for all analyzed parameters when compared with other wells.

1. Introduction

The importance of groundwater as a valuable source of potable water cannot be over-emphasized. It forms one of the most important natural resources and complement surface sources in the provision of portable water for domestic and industrial applications. Unfortunately, the quality of groundwater has been impaired by indiscriminate dumping of solid waste materials in landfill within the municipality, with attended risk to the health of the people and damage to the environment. Industrial development and uncontrolled increase of rural-urban migration that lead to growth of the urban population have resulted in an increase in the production of different types of wastes ranging from industrial to municipal, which have adverse effects on human populace via groundwater quality. Solid wastes are defined to be useless and unwanted materials arising from human activities that are not free floating [1]. Most of the cities in the country faced solid waste management problems such as poor waste collection, inadequate waste disposal equipment, an indiscriminate disposal of wastes and the selection of dumpsite without any consideration with respect to groundwater Contamination. Disposal of solid waste is a priority problem within Ibadan metropolis due to poor waste management, illegal and indiscriminate disposal of refuse at convenient locations. Several research activities have been carried out on groundwater contamination arising from solid waste disposal sites based on geochemical analyses [2-4]. For instance, [2,3] carried out geochemical analyses on groundwater sampled from hand dug wells around Orita-Aperin refuse dumpsite.

The leachate from open dumps and landfills contain both chemical and biological constituents [5]. A percolating groundwater provides a medium through which wastes, in particular organics, can undergo degradation process into simple substances through various biochemical reactions involving dissolution, hydrolysis, oxidation and reduction processes. This leachate migrates downward and contaminates the groundwater. Thus, the protection of groundwater is a major environmental issue since the importance of water quality on human health has attracted a great deal of interest lately.

The threat posed by leachates from municipal solid waste depends on waste composition, volume, temperature, lifetime, soil morphology, and the relative distance between a dumpsite and the water body used by the human community. The soil serves as the primary and ultimate recipient of solid wastes and other material deposits disposed on

*adekunsa@yahoo.com

daily basis by human beings. Millions of tons of these wastes from various sources from industrial, domestic and agricultural uses find their way into the soil. These wastes interact with the soil system thereby changing their physical and chemical properties [6]. Waste embedded soils have high content of organic matter, increase in nitrogen and cation exchange capacity [7]. Organic waste can provide nutrients for increased plant growth and such positive effect will likely encourage continued land application of these wastes [7]. However, excessive wastes in soil may increase heavy metal concentration in the soil and underground water. For example, the contamination of soil with heavy metals, even at low concentration, is known to have potential impact on environment quality as well as posing a long term risk to groundwater and ecosystem. Heavy metals may have harmful effects on soils, crops and human health [8]. This is because toxic elements accumulate in organic matter in soil and sediments taken up by growing plants [9]. These metals are not toxic as the condensed free elements but are dangerous in the form of cations and when bonded to short chain of carbon atoms [10]. The extent of contamination arising from leachates' percolation inside the soil is determined by a number of factors that include physiochemical properties of the leachates and soil together with hydrological condition of the surrounding site.

The determination of baseline information, potency of the wastes and contaminant effects on soil though soil analysis will go a long way to effectively monitor the environmental impact of the waste and provide needed information for the development of techniques for tackling the problem of soil pollutants and the effects of solid waste on the agricultural purpose.

The objective of this study were to assess the effect of solid wastes on soil properties for agricultural and landfill use and to assess the impact of landfill on groundwater quality.

2. Materials and Methods

2.1. Study area

The study area is Aba-Eku landfill located at km 13, along Akanran- Ijebu Igbo Road in Ona Ara Local Government Area of Oyo State South-Western Nigeria. The study area lies between latitude $3^0$59 009and $3^0$59 973 north of the equator and longitude $7^0$19 270 and $7^0$19 843 east of the Greenwich Meridian as shown in Fig. 1. Ibadan experiences two local climates (rainy and dry seasons). The rainy season is from March to October and the dry season from November to February, with highest rainfall of 170mm in the month of September. Temperature in Ibadan ranges from 21^0C to 35^0C. The average waste generation per capita per day in Ibadan is about 0.3kg. With an estimated population of 2,550,593 (2006 census), waste generation in Ibadan where the study area is located can be estimated to be 279,289,934 kg/year (307,864 tons per year). However, not all the wastes were disposed off at the dumpsites.

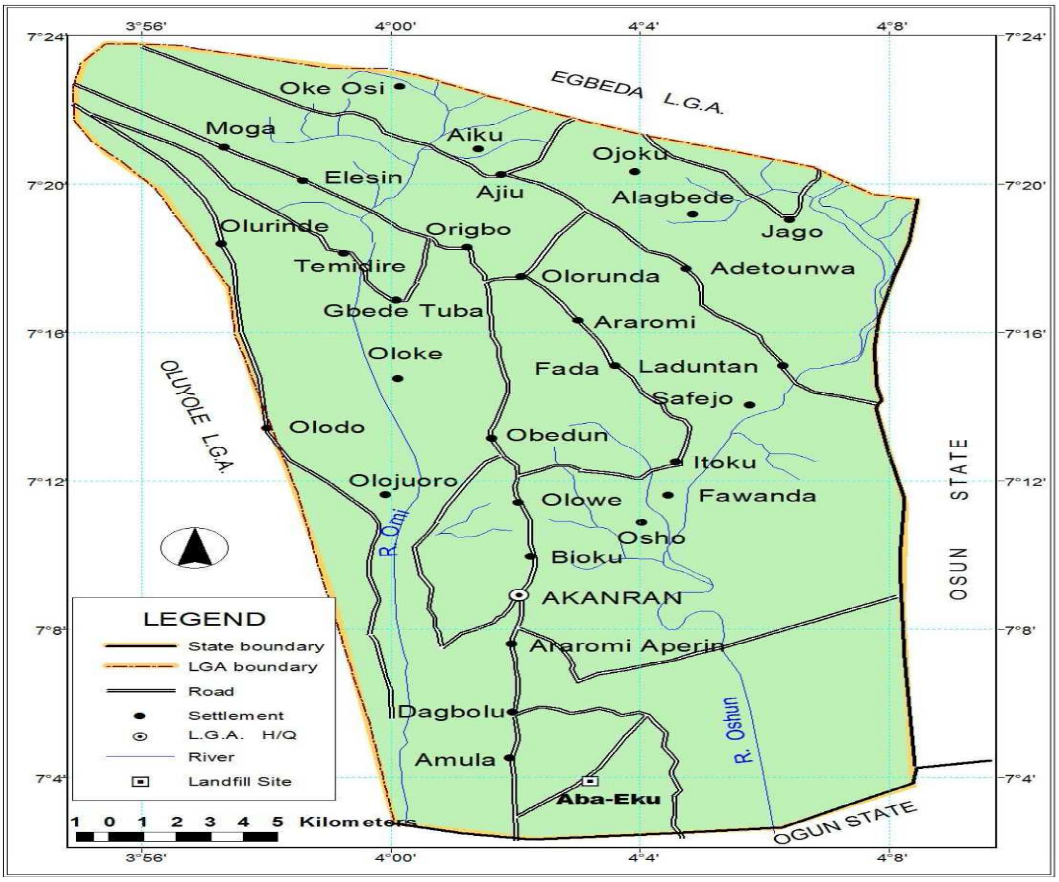

Fig.1: Map of Ona-Ara LGA showing Aba-Eku Landfill site.

3. Local Geology

The study area falls within the basement complex terrain of south western Nigeria. The basement complex rocks consist of crystalline igneous and metamorphic rocks, which form a part of the African Crystalline Shield with rocks belonging to the youngest of the three major provinces of the West African Craton. These rocks occur either exposed or covered by shallow mantle of superficial deposits. They are loosely categorized into three main subdivisions namely the migmatite-gneiss complex, the schist belt and the Pan-African (Ca.600ma) older granite series [11], which is shown in Fig. 2.

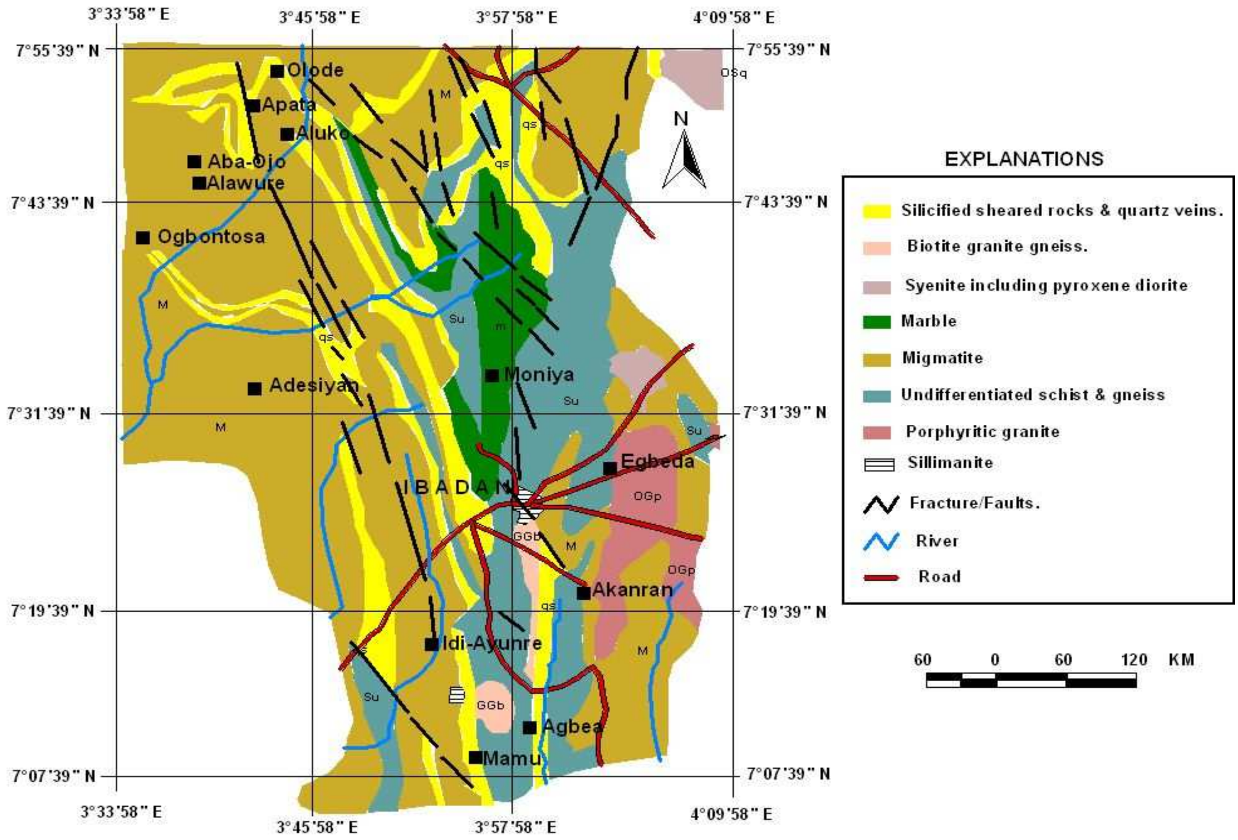

Fig.2: Generalized geological map of the study area.

3.1. Materials and Methods

3.1.1. Soil analyses

Composite soil samples were collected at depths of 40cm, 60cm, 80cm, and 100cm at four different sampling points with the aid of a soil auger. The latitude and longitude of each sampling point was taken with the aid of Hand held Garmin GPS. A control soil sample was collected about 300m away from the dumpsite during the sampling period. A total of 20 soil samples were collected across the four sampling points, packed in a labeled polythene bag and conveyed to Soil Science Laboratory of the department of Soil Science and Land Management, Federal University of Agriculture, Abeokuta (FUNAAB) for sample preparation and physiochemical analysis. The following parameters were analyzed: the soil pH, EC, organic matter content and organic carbon, and particle size. The particle size analysis was carried out using apparatus such as mechanical stirrer, stop watch, hydrometer, analytical balance, thermometer, reagents, calgon as the dispersing agent, and 50g of sodium hexametaphosphate plus 7g anhydrous sodium carbonate dissolved in 1000ml distilled water. This was done according to American Public Health Association [12] standard. The percentages by weight of silt, clay and sand fractions were calculated as follows:

% clay =

$$\frac{\text{Corrected hydrometer reading at 6hrs,52mins}}{\text{weight of soil taken}} \times 100 \quad (1)$$

$$\% \text{ silt} = \frac{\text{Corrected hydrometer reading at 40sec}}{\text{weight of soil taken}} \times 100 \quad (2)$$

$$\% \text{ sand} = 100\% - \% \text{ silt} - \% \text{ clay} \quad (3)$$

The soil pH was measured with the aid of pH meter while EC was done with the use of electrode meter. The soil organic matter and organic carbon were determined in the laboratory with the aid of 0.167

$K_2 Cr_2 O_7$, concentrated H_2So_4 titrated against 0.5m iron (II) ammonium sulphate solution. Blank determinations were similarly made and the percentage organic carbon and organic matter were calculated using the following formulae:

$$\% \text{ Organic Carbon} = \frac{(B-T)\times 0.5\times 0.003\times 1.33}{\text{weight of sample}} \times \frac{100}{1} \quad (4)$$

Where, B = Blank Titre Value, T= Sample Titre Value, F = Correction factor = 1.33, and 0.5N is the concentration of ferrous ammonium sulphate.

The weight of the sample is the weight of air dried soil taken (0.5g)

$$\% \text{ Organic Matter} = \% \text{ Organic Carbon } 1.724 \quad (5)$$

3.1.2. Water analyses

Water samples were collected from ten 10 hand-dug wells around the landfill. The water samples were collected during the dry season. Each water sample was collected inside a 2L PVC container.

For each hand-dug well, water samples were collected in 2L sterilized polyethylene bottles, stored at 4^0C and analyzed. The analysis covered physical, chemical and bacteriological parameters of water sample from each well. The qualitative chemical analysis was carried out at the water laboratory of department of Water Resource and Agrometeorology and Analytical Laboratory of Environmental Management and Toxicology Department, both of Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria.

The physio-chemical parameters analysed include: pH, Electrical Conductivity (EC), TH, TDS, Nitrate, Chloride, Sulphate, Carbonate, Bicarbonate, and major cations of Na^+, K^+, Mg^{2+} and Ca^{2+}. The pH and EC were determined *in situ* with portable conductivity and pH meters. Flame photometric and atomic absorption/emission spectro-photometry methods were used for the determination of the cations while UV – visible spectrometry, gravimetric and titrimetric methods were used for the determination of the anions. The method of Total Plate Coun was used in the determination of coliform bacteria and *Escherichia coli* (E. coli). All the results obtained were compared with the World Health Organization (WHO) standard and the Nigeria Standard for Drinking Water Quality (NSDWQ).

4. Results and Discussions

4.1. Soil analyses

The result of soil analyses in comparison with FAO are presented in Tables 1 and 2.

The mean pH value of soil samples in the study area and control site ranged from 5.45 – 6.45 indicates that soil samples are acidic in nature. The major effect of soil acidification on plants included the reduction in nutrient supply, increased concentration of metal ions in solution, especially of aluminum, copper and manganese, which may be toxic while nitrogen fixation by legumes may be reduced unless the Rhizobium strain is acid tolerant [13]. However, the pH value range indicates the soil suitability as landfill for wastes rich in heavy metal since their mobility would not be supported by pH range as most of them will be in insoluble form and hence they are unavailable to the environment. This pH range is alright for the growth of a wide range of plants as only at about pH values below 4.2 that the H^+ ions in the soil can stop or even reverse cation uptake by roots [14].

The % organic matter value ranges from 2.39 to 9.14% with a mean value of 5.71, which is higher than the control value (5.14). The higher value may have been resulted from the decomposition and composting processes of the animal wastes such as animal dung, blood, food wastes, smoke etc.

The % O.M value for all the sampling points except profile 3 are above the average level of 3% for tropical soil according to FAO standard. A high content of organic matter within the landfill favours increase moisture content, water holding capacity and permeability [15]. The result on organic matter agrees with the reported pH range of 6.0-7.0 for mineral soil and 5.0 – 5.5 for organic soils [16]. The organic matter content depends on number of factors such as level of microbial activity and proportion of organic refuse.

The values of percentage organic carbon (O.C) ranged between 1.39 and 5.30%. The values of percentage O.C within the waste dump may be as a result of burning of solid wastes on the landfill. The mean value of percentage O.C (3.31) is higher than the control value (2.98).

The soil electrical conductivity values ranged from 5.03mS/cm to 6.08mS/cm with a mean value of 6.28 mS/cm. The soil conductivity depends on factors such as soil salinity, soil texture, cation exchange capacity etc. Soil with higher percentage O.M retains much higher positively charged ions. The presence of these ions in the moisture filled soil pores will enhance soil EC [17]. According to Richards [18], classification of soil salinity, the result of EC of soil samples showed that the soil samples fall under class C, which is moderately tolerant to salinity.

Table 1: Chemical Properties of soil samples at various locations within the landfill and control site.

Profile	**pH in water**	**% O.M**	**% O.C**	**EC**	**GPS coordinate**
P_1	5.45	3.22	1.87	6.08	$7^{0}19^{1}23.13^{11}$N $3^{0}59^{1}13.16^{11}$E
P_2	5.80	9.14	5.30	6.20	$7^{0}19^{1}30.80^{11}$N $3^{0}59^{1}19.39^{11}$E
P_3	6.30	2.39	1.39	6.63	$7^{0}19^{1}32.72^{11}$N $3^{0}59^{1}09.56^{11}$E
P_4	6.45	8.09	4.69	6.20	$7^{0}19^{1}30.72^{11}$N $3^{0}59^{1}09.56^{11}$E
Control	6.40	5.14	2.98	5.03	$7^{0}19^{1}20.30^{11}$N $3^{0}59^{1}12.31^{11}$E
FAO [19]	7	3			

Table 2: Physical Properties of Soil Class (using USDA textural triangle) (in %).

Profile	**Sand**	**Silt**	**Clay**	**Textural class**
P_1	17.5	78.5	4.00	Silt-loam
P_2	5.6	3.00	91.4	Clay
P_3	85.5	9.00	5.5	Loamy-sand
P_4	10.3	68.7	21.0	Silt-clay-loam
Control	74.4	18.6	7.0	Sandy Loam

The textural soil class using the United State Department of Agriculture (USDA) textural class triangle of all profiles is shown in Table 2. The higher level of clay at profile P_2 may have occurred due to erosion that removed loose particles from the surface. The result of textural class for profile P_2 and P_4 are in line with that of high organic matter because textural class high in clay and silt are generally higher in soil organic matter.

4.2. Water analyses

The result of the analyses compared with the WHO and NSDWQ values are presented in Table 3. Their descriptive statistics are presented in Table 4 while the bacterial analysis results are presented in Table 5.

The pH of all the samples ranged from 6.69 to 7.59 and this falls within the WHO and NSDWQ permissible range of 6.5-8.5. 50% of the samples have pH value below 7.0 (acidic) and this showed presence of pollutants especially metals in the samples obtained from the wells. Well 5 has the lowest pH value. The total hardness (TH) values ranged from 08 to 288mg/L. Water sample from Well 5 has value above 200 mg/L, an indication of deposits of Ca^{2+} and Mg^{2+} ions. Their presence in water did not allow soap to form lather with water easily. The chloride ion values ranged from 17 to 106 mg/L, which is below the permissible level of 250mg/L for WHO and NSDWQ levels. However, its presence in water connotes pollution hence requires pre-treatment before use. The high value of chloride ions in Well 5 (106mg/L), close to the Aba-Eku landfill connotes the presence of weathered silicate rich rocks beneath the overburden and leaching from soil due to infiltration from the landfill. The Nitrate values ranged from 1.4 to 4.8mg/L, leaching of septic tanks, sewage, fertilizers, manure, chemical fertilizers, and wastes into groundwater results in nitrate pollution. Unpolluted natural water usually contains only minute quantities of nitrate and hence all nitrate value for all samples lie below the limit of WHO and NSDWQ. Nitrate can become a contaminant of water if its concentration exceeds 10mg/L in drinking water and all the samples fall below this limit. In drinking water, the most adverse effect of nitrate ions is methaemoglobinaemia (blue baby syndrome) affecting bottle fed infants. The low concentration of nitrate in some samples may be attributed to the decrease of nitrate through redox processes.

The values for sulphate ions ranged from 13.39 to 144.03mg/L with Well 5 have value above 100mg/L. Though, sulphate values lie below 200mg/L according to WHO and NSDWQ limit, high value of it in Well 5 is an indication of contaminant and its close proximity to Aba Eku landfill. The low values of sulphate ion in other samples are most probably due to the removal of sulphate ions by the action of bacteria [20]. Calcium level ranged from 0.1 to 5.8mg/L and lie below WHO and NSDWQ values of 75mg/L. The potassium values ranged from 0 to 5mg/L, this value support the fact that K^+ is slightly less than Na^+ in igneous rocks but more abundant in all sedimentary rocks. The main source of K^+ in groundwater is weathering of potash silicate minerals, potash fertilizers and clay minerals. Low value of it in the samples may be due to the resistant of potassium minerals to decomposition by weathering process. Also, its low concentration in natural water is as a consequence of its tendency to be fixed by clay minerals and participate in the formation of secondary minerals.

Na^+ values in the samples ranged from 8 to 40mg/L, lower than WHO and NSDWQ limits, however high value of Na^+ in Well 5 (40mg/L) and Well 2 (30mg/L) indicate contaminant of groundwater in these wells based on United State Environmental Protection Agency (USEPA) [21] standard that Na^+ levels in drinking water should not exceed 20mg/L while the WHO and NSDWQ limit is 50mg/L. The values for Mg^{2+} ranged from 0.4 to 14.8mg/L and lies below 50mg/L limit of WHO and NSDWQ. The values for Mg above 10mg/L were noticed in Well 5, which is close to the Aba Eku landfill. The values for carbonate and bicarbonate ranged from 60 to 180mg/L and 122 to 366mg/L, respectively. The primary source of Co_3^{2-} and HCo_3^- in groundwater is the dissolved carbon dioxide in the rain water that enters the soil to dissolve more carbon dioxide. The high concentration of bicarbonate in wells 5 is suspected to be as a result of the presence of carbonate rock in the area.

The EC and TDS values in all samples ranged from 148 to 784µs/cm and 74 to 392mg/L, respectively. The values for TDS are below WHO and NSDWQ limit, an indication of pollution hence the suspensions that were evident during analysis. The degree of weathering of rocks and soil beneath the ground always contribute to the level of TDS in water. EC is a valuable indicator of the amount of materials dissolved in water. Out of ten samples analyzed for bacteria, it is evident from the result that there is presence of high number of coliform bacteria in all samples and E-coli presence in wells 2 and 7 due to open defecation practice, bathing and washing of clothes near these wells. The coliform group of bacteria is the principal indicator of faecal pollution of human wastes from the landfill while the presence of E-coli in water indicate possible presence of disease causing organism such as bacteria, viruses and parasites.

The high value of coliform bacteria did not comply with WHO and NSDWQ water quality standard (1/100ml). All the samples analyzed had more than 1 in 100ml. Major treatment of water from these wells, such as chlorination, filtration and disinfection of wells [22] can be adopted before use for domestic purpose.

Table 3: Physico-chemical parameters of groundwater samples compared with WHO and NSDWQ.

Sample	pH	EC	TDS	TH	Cl^-	HCo_3^-	So_4^{2-}	No_3^-	Na^+	K^+	Mg^{2+}	Ca^{2+}	Co_3^-
S_1	7.18	207	103	74	25	170.8	19.56	1.90	17	2	7.7	2.9	84
S_2	7.07	381	190	78	68	170.8	15.65	1.63	30	1	5.6	0.8	84
S_3	6.74	227	113	84	20	219.6	14.19	1.63	15	1	9.3	2.0	108
S_4	6.83	240	120	90	25	219.6	13.39	1.36	15	1	7.1	1.7	108
S_5	6.69	784	392	288	106	366.0	144.03	2.81	40	5	14.8	5.8	180
S_6	6.95	231	115	08	25	170.8	15.00	1.45	18	1	2.7	0.9	84
S_7	7.33	176	88	26	25	146.4	14.19	2.81	13	0	0.4	0.1	72
S_8	7.59	245	122	98	17	195.2	26.94	3.99	12	1	4.1	3.9	96
S_9	6.94	263	131	116	26	219.6	42.42	1.90	12	1	12.3	4.2	108
S_{10}	7.05	148	74	60	19	122.0	26.13	4.81	8	1	4.4	0.6	60
WHO (2004) [23]	6.5. 8.5	1000	500	-	250	250.0	250.00	50	50	10	50.0	75.0	
NSDWQ (2007) [24]	6.5. 8.5		500	-	250	250.0	250.00	50	50	10	50.0	75.0	

Table 4: Descriptive Statistics of parameters.

Parameter	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
pH	6.7	7.6	7.0	0.26
EC	148.0	784.0	290.2	168.7
TDS	74.0	392.0	144.8	88.5
TH	08.0	288.0	92.2	72.2
Cl^-	17.0	106.0	35.6	27.2
HCo_3^-	122.0	366	200.1	63.4
Co_3^-	60.0	180.0	98.4	17.8
So_4^{2-}	13.4	144.0	33.2	37.9
No_3^-	1.4	4.8	2.4	0.9
Na^+	8.0	40.0	18.0	9.2
K^+	0.0	5.0	1.4	1.2
Mg^{2+}	0.4	14.8	6.8	4.2
Ca^{2+}	0.1	5.8	2.3	1.8

Table 5: Result on the microbial count for water samples.

Sample code	MA Coliform count	EMBA E-Coli
S_1	1.36×10^4	0
S_2	1.52×10^4	1
S_3	1.96×10^4	0
S_4	2.4×10^3	0
S_5	1.92×10^4	0
S_6	2.98×10^4	0
S_7	2.0×10^4	2
S_8	1.36×10^4	0
S_9	1.72×10^4	0
S_{10}	1.84×10^4	0

5. Test of Significance of Observed Correlation Coefficients

The significance of the observed correlation coefficient results are presented in Table 6. Out of the 78 correlations found between two parameters, 37 were found to have significance at 1% (P<0.01) level while 14 were found to have fairly positive correlation at 5% level (P<0.05). The 18 negative correlations were found to be between pH and EC (-0.466), pH and TDS (-0.447), pH and Cl^-(-0.419), pH and TH (-0.423), pH and So_4^{2-} (-0.400), pH and Co_3^- (-0.551), and pH and HCo_3^- (-0.551). The same goes for TDS and No_3^- (-0.059), No_3^- and EC(r= -0.060), No_3^- and HCo_3^- (-0.185), and Co_3^- (-0.185) and No_3^- and Cl^- (- No_3^- 0.089). The negative correlation coefficient also existed between pH and Na^+(-0.425), Na^+ and No_3^- (-0.264), Mg and pH (-0.646), Mg and No_3^- (-0.216), K^+ and pH (-0.460) and pH and Ca^{2+}(-0.175). This means that pH displayed a weak association with almost all the examined water chemical parameters.

A very strong positive correlation was observed to exist between EC and TDS (1.00), EC and Cl^- (0.955), EC and HCo_3^- (0.886), EC and TH (0.903), EC and So_4^{2-} (0.917), EC and Na^+ (0.923) and EC and K^+ (0.897). This buttressed the fact that EC depends largely on the quality of dissolved salt present in the sample. The same goes for TDS and Cl^- (0.955), TDS and HCo_3^- (0.886), TDS and TH (0.903), TDS and Co_3^- (0.886), TDS and So_4^{2-} (0.917), TDS and Na^+ (0.922), and TDS and K^+ (0.897).

The positive correlations also existed between Cl^- and TH (0.787), Cl^- and So_4^{2-} (0.815), Cl^- and Na^+ (0.966) and Cl^- and K^+ (0.808). Highly significant correlations were noticed between EC and TDS (1.00) and Co_3^- and HCo_3^- (1.00). Positive correlations existed between HCo_3^- and Ca^{2+} (0.815), HCo_3^- and K^+ (0.847), HCo_3^- and Mg^{2+} (0.818) and HCo_3^- and So_4^{2-} (0.867), TH and Co_3^- (0.922), TH and So_4^{2-} (0.935), TH and K^+ (0.900), TH and Mg^{2+} (0.834), and TH and Ca^{2+} (0.842). The same goes for Co_3^- and K^+ (0.847),

Co_3^- and Mg^{2+} (0.818), Co_3^- and Ca^{2+} (0.815), So_4^{2-} and Co_3^- (0.867), So_4^{2-} and K^+ (0.924), Na^+ and K^+ (0.782), and Mg^{2+} and Ca^{2+} (0.807). This is significant at 1% level. The positive relationship between TH, Ca^{2+} and Mg^{2+} is normal because Ca^{2+} and Mg^{2+} are responsible to a large extent for hardness of water. All other positive correlations between parameters are significant at 5% level.

6. Conclusions

This study revealed that the concentration of solid waste materials coupled with unhygienic practice of inhabitants around dumpsites had systematically polluted the groundwater and soil over time. The effect of wastes on groundwater parameters as determined from this study decreases as the well location farther away from the polluting source. Results of this analyses show high concentration for wells situated close to the landfill. This is in agreement with earlier work by Akinbile and Yusoff [25] that the contamination of the groundwater was more dependent on proximity to dumpsite. This study also showed that soil fertility has been altered due to waste disposal on soil within the landfill. It will however be necessary to research further into the nature and levels of possible pathogens, heavy metal and toxic organic compounds which could present in such soil prior to their use for landfill and agricultural purposes. The results obtained from microbial analysis indicated very poor sanitation practice and poor human waste management system, which have damaging effects on the health of inhabitants within the vicinity of dumpsite. Proper environmental sanitation procedure in addition to government policies on waste disposal management should be enacted and strictly enforced.

Houses should be situated far away from the landfill site to minimize pollution of nearby well water as the result from this study indicated that both the physic-chemical and microbial parameters were at variance with the WHO standard and NSDWQ value; for well nearer to the landfill (Well 5). Hence, the use of sanitary landfill with clay liners to prevent leachate from percolating the water table should be adopted.

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Table 6: Test of significance of observed correlation coefficient.

Parameters	pH	EC	TDS	Cl^-	HCo_3^-	TH	Co_3^-	So_4^{2-}	No_3^-	Na^+	K^+	Mg^{2+}	Ca^{2+}
pH	1												
EC	-.446	1											
TDS	-.447	1.000(**)	1										
Cl^-	-.419	.955(**)	.955(**)	1									
HCo_3^-	-.551	.886(**)	.886(**)	.730(*)	1								
TH	-.423	.903(**)	.903(**)	.787(**)	.922(**)	1							
Co_3^-	-.551	.886(**)	.886(**)	.730(*)	1.000(**)	.922(**)	1						
So_4^{2-}	-.400	.917(**)	.917(**)	.815(**)	.867(**)	.935(**)	.867(**)	1					
No_3^-	.471	-.060	-.059	-.089	-.185	.102	-.185	.187	1				
Na^+	-.425	.923(**)	.922(**)	.966(**)	.716(*)	.703(*)	.716(*)	.719(*)	-.264	1			
K^+	-.460	.897(**)	.897(**)	.808(**)	.847(**)	.900(**)	.847(**)	.924(**)	.043	.782(**)	1		
Mg^{2+}	-.646(*)	.670(*)	.670(*)	.547	.818(**)	.834(**)	.818(**)	.710(*)	-.216	.500	.733(*)	1	
Ca^{2+}	-.175	.665(*)	.664(*)	.462	.815(**)	.842(**)	.815(**)	.764(*)	.053	.424	.751(*)	.807(**)	1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

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